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RESEARCH ARTICLE

# Landscape context and plant community composition in grazed agricultural systems of the Northeastern United States

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**Abstract** Temperate humid grazing lands are an important component of the landscape of the northeastern United States, as well as of the economy of this region. Unlike their European counterparts, little is known about the basic ecology of managed grasslands in this region. During an 8-year survey of 28 farms across the northeastern United States, we sampled the vegetation on 95 grazed plots, identifying 310 plant species, and collected data on topography, climate and soils. Landscape structure data were obtained from the National Land Cover Data (NLCD) 2001 for six radii (250–2,000 m) surrounding each site. The 500-m radius was most strongly related to plant community composition. Planned species composition was related only to site factors, while associated species were influenced by both site factors and landscape pattern. Species richness was unrelated to landscape structure for either group. Differing management effects on planned and associated species may explain the variation in their responses. Managed grasslands are a critical part of the interconnected landscape of the northeastern United States, and both affect and are affected by their surroundings.

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## Introduction

Plant communities worldwide respond to external influences: soils, climate, topography and disturbance. The importance of site factors to plant species composition and abundance has been demonstrated repeatedly over many decades, although the relative importance of particular components may vary among communities and regions. More recently, ecologists have become interested in the effects of landscape context and structure on community composition. Surrounding land use and landscape pattern attributes such as diversity and connectivity can affect species presence and abundance at a site directly by hindering or aiding dispersal and indirectly by altering abundances of predators or herbivores and parasites.

Although most research has concentrated on animal movement within fragmented landscapes (reviewed in Mazerolle and Villard 1999), landscape factors may affect plant community richness and composition, either directly by controlling dispersal and the species pool or indirectly via effects on pollinators and pests. Most studies of plant species richness and landscape factors come from European grasslands. Few researchers used similar methods, analyzed the same measures of landscape diversity or complexity, or examined the same spatial scales. Despite this inconsistency, three types of potential landscape influences can be identified: characteristics of the sampled patch itself (size and shape); proportions of nearby land use class types; and structure of the surrounding landscape. Patch characteristics are the most clearly relevant. Species richness has been shown to be related to habitat area (Bruun 2000, 2001; Krauss et al. 2004; Simmering et al. 2006; Cousins et al. 2007), as has patch shape (Moser et al. 2002; Weibull et al. 2003; Simmering et al. 2006). Landscape heterogeneity was not related to richness in several cases (Bruun 2001; Weibull et al. 2003; Krauss et al. 2004; Cousins et al. 2007), although other studies found that surrounding land use composition was important (Soderstrom et al. 2001; Simmering et al. 2006; Marini et al. 2008). Isolation and connectivity were not significant factors (Krauss et al. 2004; Lobel et al. 2006; Cousins et al. 2007). Edge length in the surrounding landscape has been related to species richness under some conditions (Marini et al. 2008). Overall, environmental factors were more important than landscape factors as determinants of plant species richness (Bruun 2001; Lobel et al. 2006; Marini et al. 2008).

Grazed pastures are culturally and economically important in northeastern North America, and provide valuable habitat for grassland fauna (Cornell Cooperative Extension 2005; USDA-ERS 2009). Many pastures in this area are naturalized communities that have not been seeded for years or decades, and are similar in composition to European seminatural grasslands. Although cool-season grasslands were not a major feature of the landscape before European settlement, the dominant grasses are now fully naturalized throughout the region. The diversity, composition and productivity of these plant communities are influenced by site factors such as soils, topography and climate. Are these managed grasslands also affected by landscape factors, as native plant communities can be?

Cool-season grasslands in the northeastern United States are anthropogenically maintained communities and would not persist without regular interventions, most commonly grazing and possibly also mowing for hay or weed control. These grasslands are in the ecologically interesting position of being functioning ecosystems that are nonetheless entirely dependent on management. They are managed to provide a particular ecosystem service, forage production for grazing animals. Following the terminology of Swift et al. (2004), the species that are directly managed to provide this service can be termed planned species, and those that are indirectly supported or incidental are called associated species. In most agricultural systems, planned diversity consists only of the planted agronomic species. In these pastures many important forage species are naturalized, and managers often take advantage of this contribution to pasture production. The planned species are primarily naturalized European cool-season grasses and legumes, while associated species are often native or introduced forbs (Goslee, Sanderson and Tracy, unpublished data). We have chosen to treat all regionally planted forage species as planned diversity. Forage species can come from the regional species pool or from planted seed, and it is often impossible to determine the source of a particular species at a site. Regardless of origin, pasture management focuses on maintaining and increasing these species within the community. While some associated species provide forage value, they are neither considered valuable nor managed directly.

When developing grassland management plans, only site variables such as soil and topography are considered. Landscape context may be important for managed temperate grasslands, as it is for other ecosystems, but the influence of the surrounding area on these communities has rarely if ever been studied in the northeastern United States. We hypothesize that different groups of plant species respond differently to site and landscape factors. First, that the composition of planned species at a site is related to site factors, but that none of the three landscape components (patch, class, and pattern) are related to plant community composition or richness. Second, we expect that the community composition of the associated species is determined by both site and landscape factors because these species are only managed indirectly, as a side effect of grazing and forage species management. These hypotheses are tested for pasture plant community data collected across the northeastern United States. We additionally characterize the diversity and composition of these communities, investigate patterns of native and introduced species composition, and describe the landscape context of these sites at a range of spatial scales.

## Methods

Pastures were sampled on 28 farms in the northeastern United States (Fig. 1). The farms to be sampled were chosen in consultation with county and regional extension agents, who assisted us in identifying producers using rotational grazing. Because dairy dominates grazing agriculture in the northeast, most of the farms grazed dairy cows, but some had beef cattle, and one each grazed sheep and goats. On each farm, 2–8 paddocks were chosen for vegetation sampling (total of 95). These paddocks were selected to characterize the variability of the farm; so for example, one might be located in a low flat area, and the other on a slope. The history of these fields was highly variable: some had been converted from crop land within 5 years prior to sampling, while others had been grazed pastures for decades. Pasture ages were obtained from producer interviews. Most fields were managed using a rotational grazing system, with animals moved into and out of an area based on plant biomass accumulation and removal.

Vegetation sampling was conducted 1–8 times on each farm between 1998 and 2005. We used the modified Whittaker plot to sample plant species diversity and richness within each paddock (Stohlgren et al. 1995). A complete species list was recorded in the outer 1,000 m$^2$ plot (50 m $\times$ 20 m). Opposite corners of this plot were mapped with a Geographic Positioning System (GPS). A visual estimate of plant species cover was recorded for 10 1 m$^2$ quadrats located systematically within the larger plot. Mean values of species cover for each plot across all years were calculated for abundance at the 1 m$^2$ scale, and for species richness and total presence-absence at the 1,000 m$^2$ scale. The modified Whittaker plot contains richness plots at two other spatial scales (10 and 100 m$^2$), but those data were not used in this study. Nomenclature follows the US Department of Agriculture Plants Database (USDA 2005). Species were categorized as planned and associated, and were also divided into native and introduced.

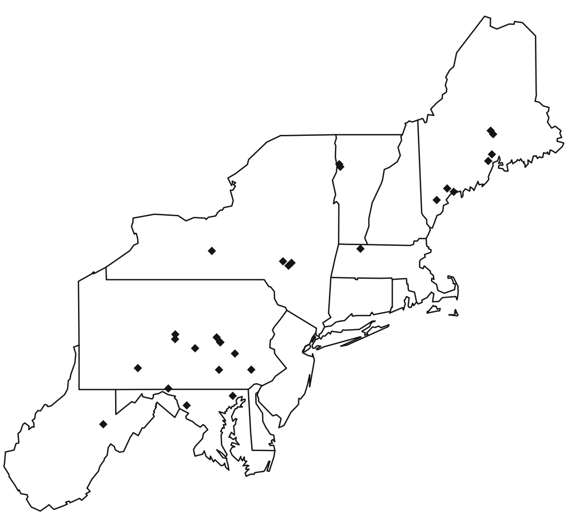


**Fig. 1** Locations of farms within the northeastern United States

US Geological Survey 7.5 min digital elevation models were used to determine elevation, slope and aspect for each plot. Because aspect is circular, aspect values of 1 and 359° are very similar despite the large numerical difference between them. To create a more tractable measure of aspect, we decomposed degrees of easting into northerly and easterly components using sine and cosine transformations. Thirty-year means of annual maximum and minimum temperatures and total annual precipitation (1971–2000) were obtained from the interpolated PRISM data (Spatial Climate Analysis Service 2006). Soil cores were taken to 15 cm at each of the 10 quadrat locations and composited for each modified Whittaker plot. Standard agronomic soil testing was done by the Penn State Agricultural Analytical Services Laboratory following protocols in Sims and Wolf (1995). A single annual sample of soil moisture would be uninformative, so estimated water table depth from the USGS soil survey maps of the area was used as a surrogate. For our sites, this captures aspects of both water availability and riparian location. Collinearity was reduced by dropping highly correlated variables ($r > 0.80$), leaving the set in Table 1.

National Land Cover Database 2001 (NLCD) data were reclassified into modified Anderson Level 1 classes to characterize four dominant land cover types (Anderson et al. 1976; Homer et al. 2007): developed, forested, row crops plowed annually, and permanent grasslands. The latter category is predominantly pasture in the areas studied, but may also include hay fields and other undeveloped grasslands. Other land use types such as water and wetlands were

**Table 1** The uncorrelated set of site variables chosen for analysis (all correlation coefficients among individual variables within each group <0.80)

| Type | Abbreviation | Description |
|---|---|---|
| Local variables[a] | | |
| | elev | Pasture elevation (m) |
| | slope | Pasture slope (%) |
| | aspN | Pasture north component of aspect (−1 for south to +1 for north) |
| | aspE | Pasture east component of aspect (−1 for west to +1 for east) |
| | ppt | Pasture mean annual precipitation (cm) |
| | tmin | Pasture mean annual minimum temperature (C) |
| | age | Approximate pasture age (yr) |
| Soil variables[b] | | |
| | pH | pH |
| | P | Phosphorus (ppm) |
| | K | Potassium (ppm) |
| | Mg | Magnesium (ppm) |
| | Ca | Calcium (ppm) |
| | CEC | Cation exchange capacity (meq/100 g) |
| | OM | Organic matter (%) |
| | sand | Sand (%) |
| | silt | Silt (%) |
| | clay | Clay (%) |
| | wt | Mean water table depth[c] |

[a] Geographic variables were measured onsite or obtained from USGS DEM data. Climate data were from PRISM maps (Spatial Climate Analysis Service 2006)

[b] Soil variables were obtained from field sampling

[c] Estimated mean water table depth was obtained from USGS soil survey maps

of only minor importance in the survey areas. All geographic and land cover data were imported into the GRASS Geographic Information System (GIS; GRASS Development Team 2008).

The effects of landscape structure on plant communities may vary with spatial scale, so all landscape variables were calculated for six different radii around the center of each modified Whittaker plot: 250, 500, 750, 1,000, 1,500 and 2,000 m. The total area and the shape of the grassland patch in which each sample was located was measured in GRASS using *r.le* (Baker and Cai 1992). Proportions of the four major land use classes within each radius were also calculated. FRAGSTATS was used to characterize landscape structure within each circle (McGarigal et al. 2002). The metrics calculated by FRAGSTATS describe seven components of overall landscape pattern, across all land use types: class area, patch size and density, edge, patch shape, nearest neighbor, landscape diversity, and contagion (Riitters et al. 1995; McGarigal et al. 2002). Only normalized metrics were used (e.g. density rather than absolute number) to maintain comparability between circles of different areas. Highly correlated metrics ($r > 0.80$) were dropped while retaining uncorrelated metrics from each of the seven pattern components, resulting in the set of landscape variables described in Table 2. These metrics were divided into three groups: patch-specific metrics, class proportions, and landscape pattern.

Mantel tests were used to identify the spatial scale at which changes in landscape factors were most strongly related to changes in plant community (Mantel 1967; Legendre and Legendre 1998; *ecodist* package for R: Goslee and Urban 2007 with 10,000 permutations). The Mantel test was chosen because this permutation-based test makes it possible to test changes in a matrix composed of one or many variables simultaneously against changes in a matrix containing many variables. Thus, richness and composition could be tested against grouped landscape variables to assess relationship strength at each spatial scale. All landscape variables were included in one matrix, and were standardized to have a mean of 0 and standard deviation of 1 before analysis. Analyses (Mantel tests and ordinations) used Bray–Curtis dissimilarity for abundance data and Jaccard

**Table 2** The uncorrelated set of landscape structure variables chosen for analysis (all correlation coefficients among individual variables within each group <0.80)

| Type | Abbreviation | Description |
|---|---|---|
| *Patch variables: Properties of the sampled patch*[a] | | |
| Area | Area | Patch area |
| Shape | ShapePA | Patch perimeter to area ratio |
| *Class variables: Land use classes in the surrounding region*[b] | | |
| Area | Devel | Area of developed land (%) |
| Area | Forest | Area of forest (%) |
| Area | Pasture | Area of pasture (%) |
| Area | Crop | Area of row crops (%) |
| *Pattern variables: Landscape pattern metrics for the surrounding region*[c] | | |
| Area | LPI | Largest patch index (%) |
| Size/density | MPS | Mean patch size (ha) |
| Size/density | PSCV | Patch size coefficient of variation (%) |
| Edge | ED | Edge density (m/ha) |
| Shape | MPFD | Mean patch fractal dimension |
| Shape | AWMPFD | Area-weighted mean patch fractal dimension |
| Neighbor | MNN | Mean nearest neighbor distance (m) |
| Neighbor | NNCV | Nearest neighbor coefficient of variation (%) |
| Diversity | PRD | Patch richness density (number/100 ha) |
| Contagion | IJI | Interspersion and Juxtaposition index (%) |

[a] Patch properties were calculated in GRASS using r.le (Baker and Cai 1992; GRASS Development Team 2008)

[b] Class proportions were derived from NLCD 2001 data (Homer et al. 2007)

[c] Landscape pattern metrics were calculated using FRAGSTATS (McGarigal et al. 2002)

dissimilarity for presence–absence data, and Euclidean distance for species richness (Legendre and Legendre 1998).

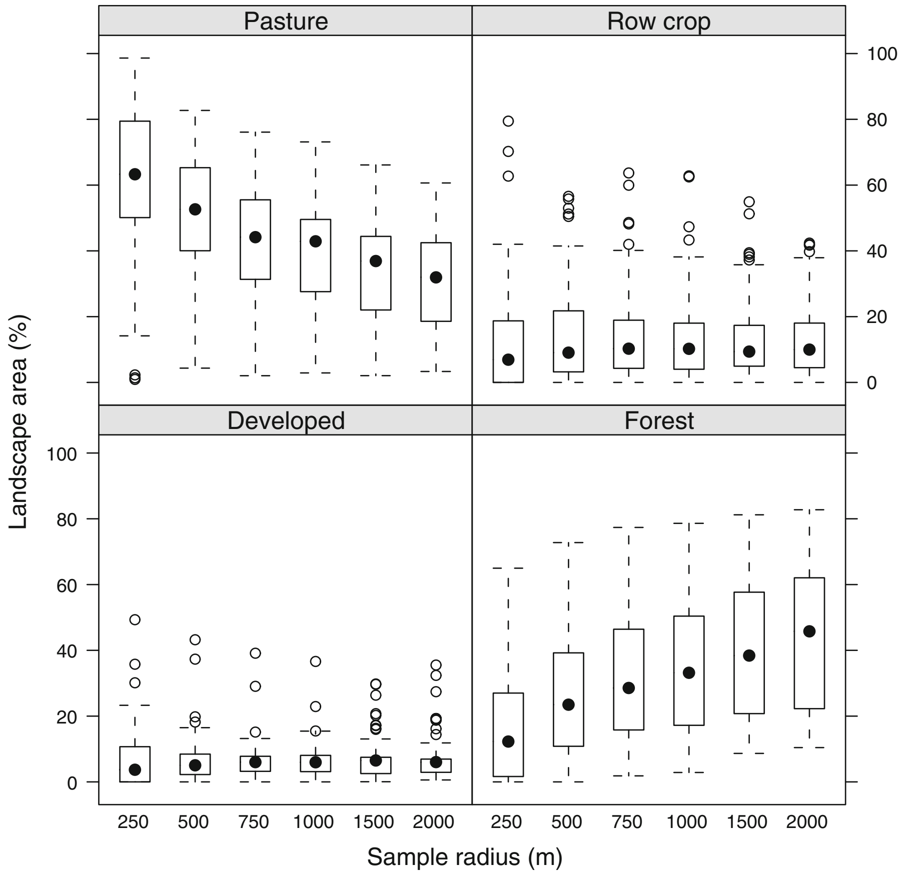
Redundancy analysis-based (RDA) variance partitioning was used to test the statistical significance of the relationship between each of three explanatory matrices (space, site variables, landscape structure) and plant community composition (Borcard et al. 1992). Spatial location was incorporated explicitly, by converting latitude and longitude into an x–y grid in km. All landscape variables (patch size and shape, land use class proportions, and landscape pattern metrics) were combined into a single matrix. The site matrix contained all local topographic, soil and climatic variables. The contributions of individual landscape and site variables were explored in more detail using constrained analysis of principal components (CAP). Ordinations were conducted using the *vegan* package (version 1.17-0; Oksanen et al. 2010) in R (version 2.10.1; R Development Core Team 2009).

## Results

The landscape of the northeastern United States is predominantly forested. Only agricultural sites were included in this study, so the immediate area is dominated by agriculture, while increasing the size of the sampling radius raises the proportion of forest and decreases the proportion of pasture (Fig. 2). Neither developed areas nor row crops changed much as a proportion of the landscape with increasing spatial scale. This pattern is characteristic of a landscape with dense patches of grassland agriculture embedded in a matrix of forest, with development scattered throughout.

In the regional survey, 310 species were found. Mean total richness was 30 species per 1,000 $m^2$. Planned species made up most of the plant canopy cover in the surveyed pastures, while associated species provided the greater part of the species richness: 292 associated species, and only 18 planned species. Nearly half of the species found were native (150), although only all but one of the planned species were introduced. Grassland species were the largest group with 248 species, 105 of which were considered native. Pasture vegetation follows the frequency-abundance pattern seen in many plant communities, where a few species are dominant, and most species are rare. Only a few species were found on more than half of the farms sampled (Table 3). Planned species richness varied over only a small range (4–11 species;

**Fig. 2** Proportion of the landscape occupied by each of the four dominant land use classes at six different spatial scales




mean = 8), while associated and thus total richness varied widely, with 4–55 (mean = 22) species found per 1,000 $m^2$ plot. Planned species comprised most of the vegetation, with mean cover for this group of 82%. Planned species richness was unrelated to richness of associated species (Spearman $r = 0.15$; $P = 0.138$).

Species richness was most strongly related to landscape structure measured at 500 and 750 m, but also at 2,000 m (Table 4). Species presence in the 1,000 $m^2$ plots was strongly related to landscape structure at all radii, while abundance from 1 $m^2$ plots was related to landscape structure at intermediate radii: 500–1,000 m. Landscape metrics measured at 500 m were the best fit for all three plant community descriptors, so that scale was chosen for use in the ordination analyses. The median distance apart of sampled pastures was 490 m, and the maximum distance was 13,300 m (first and third quartiles 300 and 1,021 m, respectively), so using this smaller distance reduced but did not eliminate overlap in sampled circles.

Variance partitioning results indicated that richnesses for all categories of species were unrelated to landscape pattern or to space, and that site factors were only significant for planned species richness (pure partials only; Table 5). Planned species presence at 1,000 $m^2$ was more sensitive to both site and landscape factors for all groups of species. Site variables were the most strongly related in each case, but significant relationships with landscape structure were seen for all groups other than planned species. Native species abundances at 1 $m^2$ were unrelated to space, site, or landscape factors but abundances of all other groups were significantly related to site variables. Only abundances of associated species were related to landscape structure.

When planned species presence-absence data were ordinated on site variables and landscape pattern metrics within a 500-m radius, the constrained variables explained 84% of the total variance (Fig. 3a; $P = 0.005$). This ordination identified east aspect, minimum temperature and water table depth

**Table 3** Most common planned and associated species (found on more than half the farms sampled)

| Species | Common name | Scientific name | No. sites (%) | Mean cover (%) |
|---|---|---|---|---|
| *Planned species* | | | | |
| DAGL | Orchard grass | *Dactylis glomerata* L. | 87.4 | 11.7 |
| LOAR10 | Tall fescue | *Lolium arundinaceum* (Schreb.) S.J. Darbyshire | 95.7 | 12.8 |
| LOPE | Perennial ryegrass | *Lolium perenne* L. | 60.0 | 4.2 |
| PHPR3 | Timothy | *Phleum pratense* L. | 86.3 | 5.3 |
| POPR | Kentucky bluegrass | *Poa pratensis* L. | 97.9 | 22.9 |
| TRPR2 | Red clover | *Trifolium pratense* L. | 97.9 | 3.7 |
| TRRE3 | White clover | *Trifolium repens* L. | 97.9 | 16.6 |
| *Associated species* | | | | |
| CEFO2 | Mouse-ear chickweed | *Cerastium fontanum* Baumg. | 55.8 | 0.2 |
| CIVU | Bull thistle | *Cirsium vulgare* (Savi) Ten. | 64.2 | 0.2 |
| DACA6 | Wild carrot | *Daucus carota* L. | 58.9 | 0.8 |
| ELRE4 | Quack grass | *Elymus repens* (L.) Gould | 86.3 | 4.2 |
| ERAN | Daisy fleabane | *Erigeron annuus* (L.) Pers. | 68.4 | 0.3 |
| OXST | Yellow wood sorrel | *Oxalis stricta* L. | 67.4 | 0.2 |
| PLLA | English plantain | *Plantago lanceolata* L. | 68.4 | 1.0 |
| PLMA2 | Common plantain | *Plantago major* L. | 93.7 | 2.5 |
| RAAC3 | Tall buttercup | *Ranunculus acris* L. | 64.2 | 0.8 |
| RUCR | Curly dock | *Rumex crispus* L. | 76.8 | 0.2 |
| TAOF | Dandelion | *Taraxacum officinale* G. H. Weber ex Wiggers | 100.0 | 7.6 |

Of the 18 species listed, only *E. annuus* and possibly *T. officinale* are native to the northeastern United States. Abbreviations and nomenclature follow USDA-NRCS Plants Database (2005)

**Table 4** Plant community composition compared to landscape structure measured in circles of six different radii

| Radius (m) | Species richness[a] | | Presence in 1,000 $m^2$ | | Abundance[b] in 1 $m^2$ | |
|---|---|---|---|---|---|---|
| | *r* | *P*[c] | *r* | *P* | *r* | *P* |
| 250 | 0.05 | 0.226 | *0.10* | 0.006 | 0.06 | 0.109 |
| 500 | *0.14* | 0.020 | *0.22* | 0.000 | *0.12* | 0.016 |
| 750 | *0.12* | 0.034 | *0.24* | 0.000 | *0.12* | 0.018 |
| 1,000 | 0.09 | 0.081 | *0.25* | 0.000 | *0.10* | 0.029 |
| 1,500 | 0.10 | 0.058 | *0.25* | 0.000 | 0.05 | 0.185 |
| 2,000 | *0.14* | 0.018 | *0.27* | 0.000 | 0.04 | 0.221 |

Landscape variables (patch, class and landscape pattern) are given in Table 2. *Italicized*: test statistics are significant at $P = 0.05$

[a] Species richness and presence were mean values from 1,000 $m^2$ plots averaged across all sampling dates

[b] Abundances were mean cover values from 10 1 $m^2$ plots located within the 1,000 $m^2$ plots used for sampling species presence

[c] significance was assessed using Mantel tests with 10,000 permutations

as significant. When abundance data were analyzed, the constrained variables explained 74% of the total variance (Fig. 3b; $P = 0.005$). Only water table depth and pasture age were significant. Presence-absence for associated species was related to the same set of variables as abundance, and also to soil phosphorus, precipitation, and surrounding forest area (Fig. 3c; 66% constrained; $P = 0.005$). Associated species abundances were related to minimum temperature and elevation, and to the IJI metric of landscape complexity (Fig. 3d; 64% constrained; $P = 0.005$). Constrained ordinations for both native and introduced species were very similar to those for associated species, and are not shown. We found no

**Table 5** Variance partitioning and significance testing of variance related only to each of three measures of plant community composition: space (geographic position), site factors (local and soil attributes), and landscape structure (patch, class and landscape pattern variables) measured within a 500-m radius

| | Species richness | | Presence, 1,000 $m^2$ | | Abundance, 1 $m^2$ | |
|---|---|---|---|---|---|---|
| | adj. $R^2$ | *P* | adj. $R^2$ | *P* | adj. $R^2$ | *P* |
| *All species* | | | | | | |
| All | *0.50* | 0.005 | *0.28* | 0.005 | *0.33* | 0.005 |
| Space | −0.02 | 0.820 | *0.04* | 0.005 | 0.01 | 0.230 |
| Site | 0.12 | 0.066 | *0.08* | 0.005 | *0.08* | 0.010 |
| Landscape | 0.09 | 0.097 | *0.04* | 0.015 | 0.03 | 0.130 |
| *Planned species* | | | | | | |
| All | *0.46* | 0.005 | *0.34* | 0.005 | *0.33* | 0.005 |
| Space | 0.03 | 0.130 | *0.02* | 0.023 | −0.01 | 0.780 |
| Site | *0.24* | 0.017 | *0.14* | 0.005 | *0.07* | 0.033 |
| Landscape | 0.11 | 0.075 | 0.02 | 0.250 | 0.00 | 0.440 |
| *Associated species* | | | | | | |
| All | *0.45* | 0.005 | *0.28* | 0.005 | *0.34* | 0.005 |
| Space | −0.02 | 0.870 | *0.04* | 0.005 | *0.07* | 0.005 |
| Site | 0.13 | 0.068 | *0.07* | 0.005 | *0.11* | 0.005 |
| Landscape | 0.05 | 0.103 | *0.04* | 0.010 | *0.11* | 0.010 |
| *Native species* | | | | | | |
| All | *0.40* | 0.010 | *0.25* | 0.005 | 0.13 | 0.100 |
| Space | −0.02 | 0.730 | *0.05* | 0.005 | 0.01 | 0.370 |
| Site | 0.12 | 0.150 | *0.06* | 0.005 | 0.05 | 0.210 |
| Landscape | 0.06 | 0.320 | *0.03* | 0.027 | 0.04 | 0.320 |
| *Introduced species* | | | | | | |
| All | *0.52* | 0.015 | *0.30* | 0.005 | *0.35* | 0.005 |
| Space | −0.01 | 0.810 | *0.03* | 0.005 | 0.01 | 0.330 |
| Site | 0.11 | 0.061 | *0.08* | 0.005 | *0.08* | 0.017 |
| Landscape | 0.10 | 0.260 | *0.04* | 0.005 | 0.03 | 0.230 |

*Italicized*: test statistics are significant at $P = 0.05$

effect of the size or shape of patch sampled. As was seen for in the variance partitioning analyses, associated species responded to more site and landscape variables than did planned species, and community composition measured by abundance was less sensitive than that measured by presence–absence.

## Discussion

Planned species composition was related to site factors but not to landscape structure while associated species composition was related to both site and landscape factors, consonant with our predictions. Planned species abundances are determined primarily by management practices such as grazing intensity and timing, mowing, and planting. Minor species were present on most farms, contributing much richness but little abundance. Both abundance and presence of associated species were related to class and landscape metrics, although site variables were the most important. Dividing plant species into planned and ancillary species is a useful tool for studying these communities because this division conforms to the way that these grasslands are managed. These two groups of species demonstrated distinct responses to potential explanatory variables, supporting this choice. The other groups examined, native/introduced and grassland species, were less distinctive in their responses to site and landscape factors.

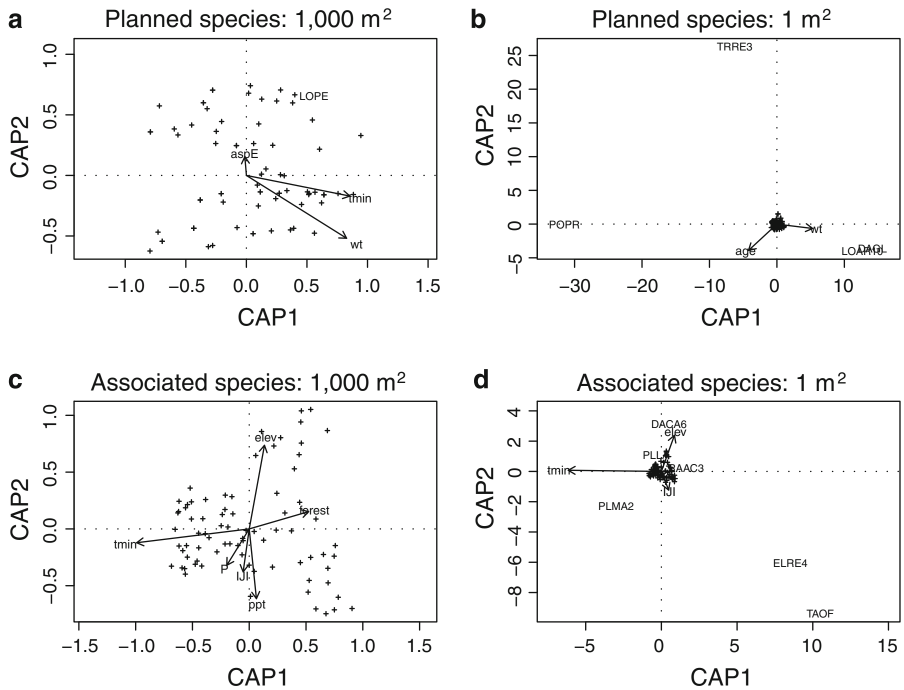



**Fig. 3** Constrained principal components analysis of presence at 1,000 $m^2$ and species abundances at 1 $m^2$ for planned (**a**: presence; **b**: abundance) and associated species (**c**: presence; **d**: abundance). Site scores are shown by *plus* and *arrows* indicate potential explanatory variables significant at $P = 0.05$. Only dominant species that are also important for that ordination are shown. Ordinations include all site variables (local and soil) but only patch, class and landscape variables measured at the 500-m radius

Unmanaged species come either from the seed bank or from the surrounding area. Both the shape and distribution of landscape patches and the proportion of different land cover types within the surrounding area influence the availability and transport of propagules, whether by wind, birds and animals, or through agricultural activities via hay or manure (Zeleny et al. 2010). We identified the interspersion and juxtaposition index and the percentage of forest in the surrounding landscape as the only landscape pattern metrics related to associated species diversity. Of the four land use classes that dominate the landscape of this region, forest is the most likely to contribute different species to a pasture, even if only temporarily. Increased interspersion and high proportion of forest cover alters composition of associated species. Landscape complexity has been identified as one factor contributing to local diversity in agricultural landscapes (Tscharntke et al. 2005). Site environment was far more important than landscape context: landscape contributes to the species pool, and site environment determines which species will thrive. Our intent was to capture the diversity inherent in agricultural grasslands by sampling the widest possible range of site types. Restricting sampling to one type of site would have reduced the importance of environmental factors by reducing both site and compositional diversity, but would not be representative of the grassland agriculture of the northeastern United States.

Although most studies of the effects of landscape context on grassland plant communities have looked only at species richness (e.g. Bruun 2000, 2001; Moser et al. 2002; Weibull et al. 2003; Krauss et al. 2004; Simmering et al. 2006; Cousins et al. 2007; Marini et al. 2008), this community descriptor was the least sensitive measure examined. Use of richness alone would have led to much different conclusions since for no group was richness related to landscape pattern. Many studies of richness alone have found no landscape matrix effects (e.g. Eriksson et al. 1995; Dauber et al. 2003). Although significant relationships between species richness and environmental factors have been identified in other studies (e.g. Kumar et al. 2006), richness alone is not a good description of a plant community; composition must also be considered.

The accuracy of the land use data could greatly affect the results presented here. The accuracy assessment of the 2001 NLCD data has just been released (Wickham et al. 2010). At a level I classification, overall user accuracy was 80–90 and 78–82% for agricultural land uses within in the three assessment regions that comprise the northeastern United States. Distinguishing row crops from agricultural grassland was more challenging, and had a lower accuracy rate. User accuracy was 51–76% for pasture/hay and 65–88% for cultivated crops, with a 4.4% misclassification rate. Informal comparison of the NLCD data with aerial photography of the neighborhoods surrounding the study sites suggests that the grassland regions delineated in the 2001 NLCD data were reasonable. While individual pixels were certainly misclassified, we are confident that the broader patterns observed represent the actual landscape.

Since planned species composition was not strongly related to landscape factors, grazing land managers in the northeastern United States probably do not have to consider landscape context when planning their pastures, although species mixes should be tailored to climate and soils for greatest success. The composition and abundance of associated species did depend on landscape context, probably due to propagule dispersal effects, but associated diversity is rarely considered by managers except in the context of noxious species control. From an ecological perspective, associated species comprise the majority of the diversity in these systems. Over half of these ancillary species were native, and contribute to regional biodiversity here, just as they do in European agricultural landscapes (Klimek et al. 2007). Managed grasslands are a critical part of the interconnected landscape of the northeastern United States, and both affect and are affected by their surroundings.

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